

# VRJ Loss Prevention: A Loss Prevention Tool for Petrochemical Plants

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## **Abstract**

VRJLossPrevention is a program that has been developed to provide a rigorous method of estimating the expected losses associated with hazardous events in the process industries. The estimates can be used for insurance purposes when renewing policies.

VRJLossPrevention utilises consequence models for pool fires, jet fires and explosions from the quantified risk assessment programs ORCA and VRJQRA2. Using the results of these models, the damage that would be expected for exposed items of equipment can be calculated and combined to produce estimates of the property loss that would result from a major accident. Different measures of loss can be calculated by varying the assumptions used.

The main benefits of the approach are that the technical basis of the loss calculations provides loss estimates that are consistent and site-specific, rather than based on generic industry loss averages. This provides a solid foundation for negotiations with insurance companies when renewing premiums and enables the insurance companies to have greater confidence in the loss expectancy values put forward, than those calculated by less rigorous means.

## **Introduction**

Most process plants carry insurance policies with external insurance companies to cover losses associated with major accidents. The sum that a plant insures for consists of two components, namely business interruption (BI) and property damage (PD). BI is the flow-on loss associated with the inability of the facility to operate fully due to the impact of the accident. PD is the loss due to damage to equipment and other items from the accident.

This paper is concerned with the calculation of PD loss. PD is based on several measures of loss. The terms used and their meanings can vary somewhat. Alexander (1990) defines the following terms and definitions:

- normal maximum loss (NML)                      The maximum loss that would occur if all protective equipment functions correctly.
- estimated maximum loss (EML)                      The maximum loss that would occur if one critical item of protective equipment does not function correctly.

- maximum credible loss (MCL)                      The maximum loss that would occur if a number of critical items of protective equipment do not function or where a credible catastrophic event occurs.

VRJLossPrevention is a program that can be used to determine the loss estimate in a more in-depth manner than is customarily employed. Any specific loss estimate (i.e.: NML, EML, MCL or any other alternative measure) can be evaluated, by simply modifying the assumptions used.

### ***Methodology***

Traditionally the loss estimates have been evaluated by an assessor, following an inspection of the site. These estimates are usually based on generic historical experience, personal opinion and non-transparent calculation methodologies. This method can be inaccurate, inconsistent and lacks traceability. This can lead to larger insurance premiums, as the insurers will generally apply additional safety factors to estimates made by these means.

VRJLossPrevention provides an analysis of the loss expectancy that is specific to the site under consideration, taking into account risk control and protective measures as appropriate. The steps in the calculation procedure for expected maximum loss are as follows:

- Scenario Selection
- Consequence Modelling
- Damage Impact Level Assessment
- Asset Valuation
- Loss Calculation

These stages are discussed in the following sections.

### ***Scenario Selection***

Events with the potential for major damage should be considered in the analysis. In a process plant, this typically includes major failures that would result in pool fires, jet fires or vapour cloud explosions. Specific aspects of the modelling of each of these consequence types are discussed below.

### ***Consequence Modelling***

The loss calculation process utilises the consequence calculation models contained in VRJ's risk analysis programs ORCA and VRJQRA2. These models are described briefly below.

## Vapour Cloud Explosions

Explosion overpressure has been estimated using the Multi-Energy Damage model (van den Berg, 1985). This model is considered to provide better estimates of the overpressure than TNT equivalency methods. TNT equivalency methods are described by CCPS (1994).

The Multi-Energy Damage model is based on the assumption that the explosion occurs in regions of the vapour cloud that are partially confined or contain obstructions, such as areas that are congested with equipment. The strength of the blast is dependent on the nature of these confined or obstructed regions. These confined areas in the plant need to be identified and the volume contained within estimated. This is normally based on a review of the plant layout and site inspections.

When considering the possible explosions to model, allowance should be made for cloud drift from the release location to a congested area. Gas dispersion modelling should be performed to determine the congested areas (i.e.: a potential explosive blast generation location) that will be reached by the flammable vapour cloud resulting from the failure scenarios being considered.

## Pool Fires

The pool fire model used is that proposed by Mudan and Croce (1988). This is a solid flame model, which allows for a more accurate representation of the fire's flame and its thermal impacts than a point source model.

The pool area of the pool fire is a critical parameter that needs to be estimated, as the impact zones for a pool fire increase significantly with increasing pool size. The estimate of this needs to be based on the release rate, ground surface and drainage characteristics.

## Jet Fires

The jet fire model used is that described by Chamberlain (1987) and Johnson, Brightwell and Carsley (1994). This is a solid flame model that enables the orientation of the jet fire and the effects of the prevailing wind to be taken into account. This ensures that impacts of the fire are modelled realistically.

## ***Damage Impact Level Assessment***

The consequence modelling provides estimates of the zones affected by selected impact levels for each of the scenarios being analysed. In order to estimate the loss from an event, the impact levels must be related to the damage that would be sustained by exposed equipment and structures.

Differing impact levels can be assigned to different equipment or structure categories, depending on their susceptibility to damage. Typical damage sustained by categories of equipment are presented for thermal radiation and explosion overpressure.

## Explosion Overpressure

Impacts of explosion overpressure on structures are described in Table 1 (New South Wales Department of Planning, 1992; API RP 752, 1995; and IChemE, 1994).

**Table 1: Explosion Overpressure Effects**

<b>Overpressure</b>	<b>Observed Effect</b>
1kPa	Glass breakage.
3kPa	90% glass breakage, gauges break
7 kPa	Repairable damage to internal partitions and joinery. Cone roof storage tank collapse.
14 kPa	House uninhabitable and badly cracked. Fired heater bricks crack.
21 kPa	Wagons and plant items overturned. Half filled cone roof storage tank uplifts. Unreinforced masonry bearing wall building destroyed.
35 kPa	Regenerator bracing fails and frame collapses. Unreinforced steel or concrete frame building destroyed.
70 kPa	Many types of process vessels overturned or destroyed.

A given level of damaging energy may have different impact levels, depending on the type of structure that is being affected. Based on information on the potential damage caused, asset damage percentages have been applied. Different structures have different damage thresholds, and, therefore, the asset damage percentages are varied depending on the category of the exposed structure. The impact levels used are given in Table 2.

**Table 2: Explosion Overpressure Damage Levels**

<b>Explosion Overpressure</b>	<b>Damage Level</b>		
	<b>Buildings</b>	<b>Process Equipment</b>	<b>Storage Tanks</b>
1	5%	—	—
3	10%	5%	5%
7	30%	10%	10%
14	60%	30%	50%
21	100%	60%	100%
35	—	100%	—

As the cost of repair for a heavily damaged item is likely to exceed the replacement cost of the item, the impact levels used for total loss of the asset are lower than corresponding damage levels observed.

## Thermal Radiation

Impacts of thermal radiation on structures are listed in Table 3 (New South Wales Department of Planning, 1992; World Bank, 1985).

**Table 3: Thermal Radiation Effects**

Heat Flux	Observed Effect
35 - 37.5 kW/m <sup>2</sup>	Sufficient to cause damage to process equipment. Cellulosic material will pilot ignite within one minute's exposure.
23 – 25 kW/m <sup>2</sup>	Spontaneous ignition of wood after long exposure. Unprotected steel will reach thermal stress temperatures which can cause failures. Pressure vessel needs to be relieved or failure will occur.
12.6 kW/m <sup>2</sup>	Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure. Minimum energy required for piloted ignition of wood, melting of plastic tubing.

The impact levels assigned for use in the analysis are presented in Table 4.

**Table 4: Thermal Radiation Damage Levels**

Heat Flux (kW/m <sup>2</sup> )	Damage Level
4.7	10%
8	30%
12.6	50%
18	80%
23	100%

The available information on the effects of heat radiation does not differentiate between various types of structures. Therefore a single set of damage criteria has been used for the impacts of heat radiation.

### **Asset Valuation**

The method of asset valuation used in the analysis is limited by the available information for the site under investigation. The asset values will generally be in one of two formats:

- overall valuations for a selected section of the plant; or
- individual equipment item or building asset valuations.

The preferred format is for valuations of individual equipment items, as this will provide a more accurate result. If this is not available, overall valuations for specific plant sections can be used. In cases such as this, it is assumed that the value is distributed evenly across the plot area of the plant section. Where the value of a plant area may be concentrated in a particular sub-section due to the presence of high value equipment items, this can be accounted for by assigning a proportionally higher value in this area.

An example of the asset calculator that is used for recording the details of each asset is shown in Figure 1. The calculator allows for the inclusion of a photograph and comments

pertaining to any assumptions made in the analysis, as well as the asset value and percentage damage levels used in the analysis for that item.

### **Loss Calculations**

The expected maximum loss for each scenario is calculated by determining the equipment items located in each of the consequence zones and then combining the asset values and damage levels according to the following equation.

$$Total\ Loss = \sum_{i=1}^{no.\ of\ equipment\ items} (asset\ value)_i \times (asset\ damage)_i$$

This process is repeated for each scenario. For pool fires, the wind direction is taken into account, and for jet fires, the jet orientation and wind direction are both taken into account. An example of the consequence analysis is shown in Figure 2. This example is of a tank-top fire and its impacts on nearby tanks. Figure 3 shows the output from the damage calculator, which determines the maximum loss for the scenario under consideration. The calculator lists the various assets that are affected by the incident, along with the percentage damage and the value of the damage to the asset. Specific assets that are vulnerable to particular incidents can be readily identified from this output.

The calculations do not take into account shielding from other vessels, nor do they allow for active protection measures such as deluge systems. The effective action of protective systems can be allowed for by entering a value for the maximum value of the damage that the item would sustain with the protective system operating, and performing the calculations on this basis.

The computer program VRJLossPrevention performs the calculations outlined above rapidly to determine the worst-case loss expectancy. A range of scenarios can be readily investigated to determine the potential impacts. By varying the assumptions used, different measures of loss (i.e.: NML, EML, MCL or any other alternative measure) can be calculated as required. Ranking of the types of loss scenarios analysed can be readily undertaken.

### **Utilisation Strategy**

The methodology presented above enables the property damage loss from major incidents at petrochemical plants to be evaluated in a more rigorous technical manner. The results of the analysis can be used as the basis of a case to the company's insurers for a reduction in premium, based on financial risk exposure.

The results of the analysis can be compared to the industry loss averages that are used by the insurance industry to determine premiums. If the loss expectancy is lower than the industry average, this information can be used to argue for a reduction in premium based on the financial risk exposure. Should the loss expectancy be higher than the industry average, this will highlight areas of the site where additional risk reduction effort may be required.

This may take the form of improved protective systems or even redesign of part of the process.

VRJ Risk Engineers has used this methodology successfully for several clients. In one case, the client received a significant reduction in premium, despite the calculated loss values being much greater than any that had been previously calculated for the operation. The technical basis of the analysis was considered by the insurers to provide a more reliable estimate of the loss from an incident, and therefore the insurers had more confidence that the premiums they determine are appropriate for the risk exposure.

### **Conclusions**

A methodology is proposed for estimating the loss expectancy for major accidents in petrochemical plants utilising consequence modelling tools normally used in quantitative risk analysis. The methodology combines the impact zones and damage levels for accident scenarios with asset valuations to estimate the resultant loss. The technical basis of the loss calculations provides a solid foundation for negotiations with insurance companies when renewing premiums, and enables the insurance companies to have greater confidence in the loss expectancy values put forward, than those calculated by less rigorous means.

### **References**

- Alexander, L.M., (1990). "Chemical Plant Underwriting and Risk Assessment – a personal view," Safety and Loss Prevention in the Chemical and Oil Processing Industries, p75
- API RP 752 (1995) "Management of Hazards Associated with Location of Process Plant Buildings".
- van den Berg, A.C., (1985). "The multi-energy method. A framework for vapour cloud explosion blast prediction." J. Haz. Materials, **12**(1), 1-10.
- Centre for Chemical Process Safety (1994). "Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs." American Institute of Chemical Engineers, 112-122.
- Chamberlain, G.A. (1987). "Developments in Design Methods for Predicting Thermal Radiation from Flares." Chem. Eng. Res. Des, **65**, 299-309.
- Institution of Chemical Engineers (1994). "Explosions in the Process Industries", 2<sup>nd</sup> edition
- Johnson, A.D., Brightwell, H.M. and Carsley, A.J. (1994). "A Model for Predicting the Thermal Radiation Hazards from Large-Scale Horizontally Released Natural Gas Jet Fires." Trans IChemE Part B, **72**, 157-166.
- Mudan K.S. and Croce P.A. (1988). "Fire Hazard Calculations for Large Open Hydrocarbon Fires." The SFPE Handbook of Fire Protection Engineering, NFPA, pp2-45 to 2-87.
- New South Wales Department of Planning (1992) "Guidelines for Hazard Analysis." Hazardous Industry Advisory Paper No.6 (HIPAP No.6), Sydney.
- World Bank (1985). "Manual of Industrial Hazard Assessment Techniques." Washington.

First	Prev	Enter
Last	Next	Cancel

Analyst

Location x  y

Asset Identifier

Any relevant additional comments can be displayed in this field, such as comments on specific maintenance or loss prevention issues that are relevant. Any assumptions made for this item in relation to the loss estimate calculations can also be recorded here.

Estimated Asset Value  (\$)

Heat Flux

	Heat Flux (kW/m2)	Effect (%)
Level 1	<input type="text" value="4.7"/>	<input type="text" value="10"/>
Level 2	<input type="text" value="8"/>	<input type="text" value="30"/>
Level 3	<input type="text" value="12.6"/>	<input type="text" value="50"/>
Level 4	<input type="text" value="18"/>	<input type="text" value="80"/>
Level 5	<input type="text" value="23"/>	<input type="text" value="100"/>
Level 6	<input type="text"/>	<input type="text"/>

Overpressure

	Overpressure (kPa)	Effect (%)
Level 1	<input type="text" value="3"/>	<input type="text" value="5"/>
Level 2	<input type="text" value="7"/>	<input type="text" value="10"/>
Level 3	<input type="text" value="14"/>	<input type="text" value="50"/>
Level 4	<input type="text" value="21"/>	<input type="text" value="100"/>
Level 5	<input type="text"/>	<input type="text"/>
Level 6	<input type="text"/>	<input type="text"/>

Picture File Name

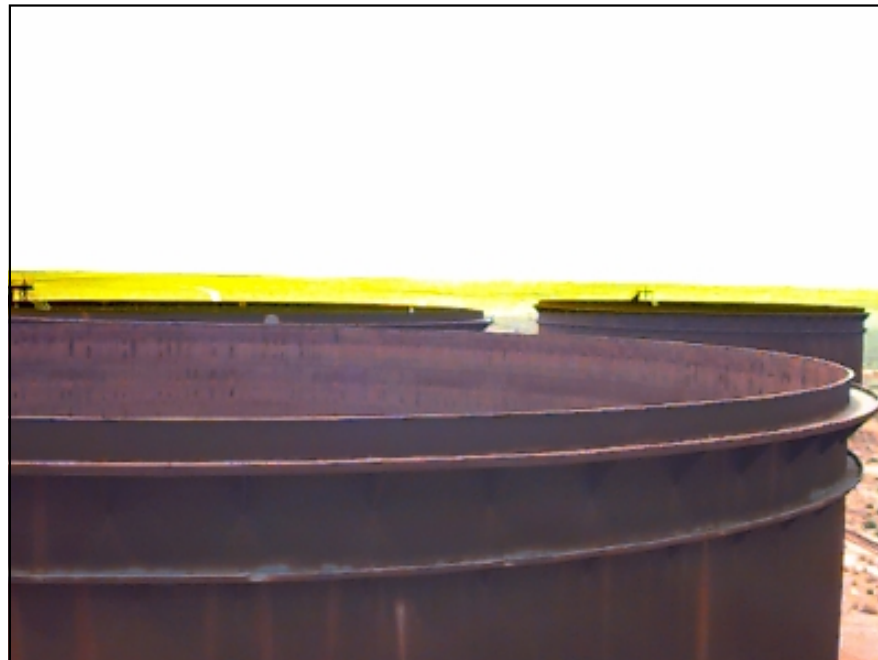
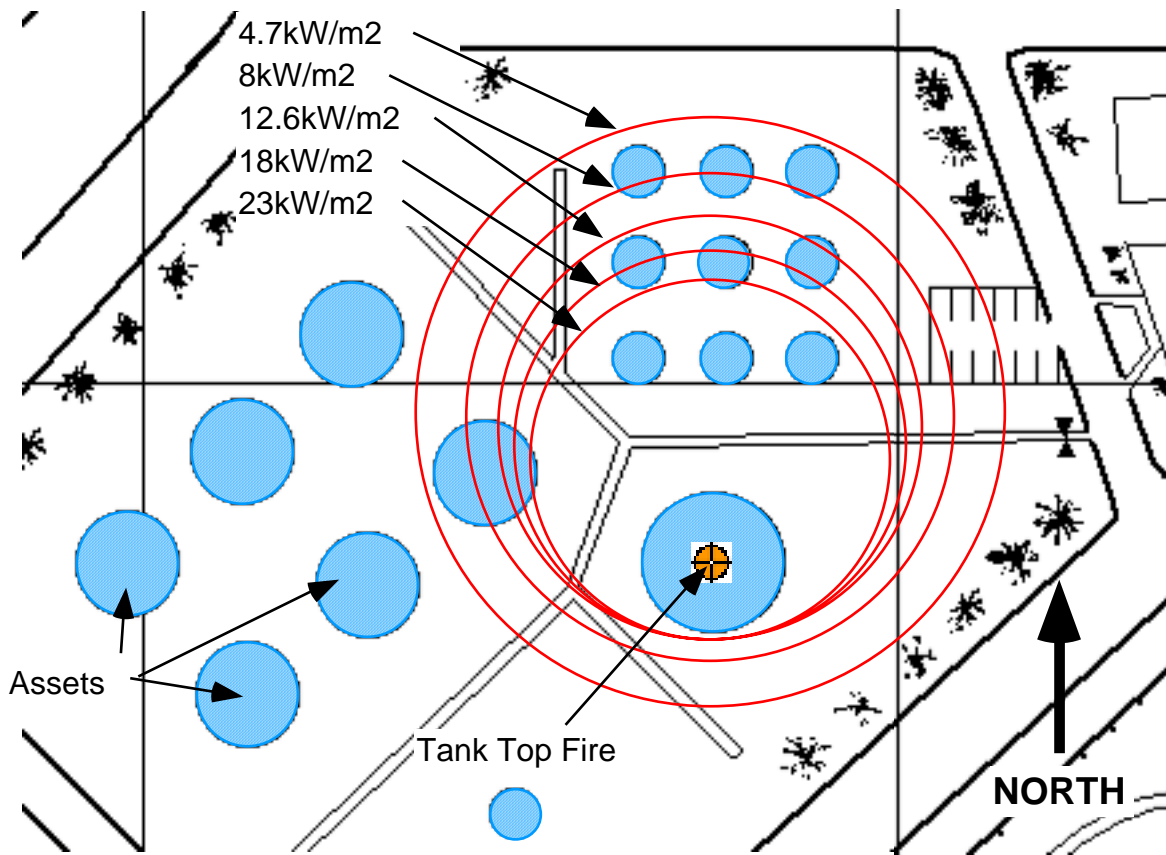


Figure 1: Example Asset Calculator



**Figure 2: Example Calculation Output**

Incident / Damage Calculator ©1996

VRJIS Analyst

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Location  x  y

Incident Identifier

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Calculate Worst Case		Assets Affected	% Damage	Loss (A\$)
Wind Direction	<input type="text" value="S"/>	Storage Tank T-1	100	5,000,000
Stability Number	<input type="text" value="1"/>	Storage Tank T-16	100	2,500,000
Total Loss (A\$)	<input type="text" value="14,000,000"/>	Storage Tank T-21	30	300,000
		Storage Tank T-26	100	1,000,000
		Storage Tank T-27	100	1,000,000
		Storage Tank T-28	100	1,000,000
		Storage Tank T-29	30	300,000
		Storage Tank T-31	30	300,000
		Storage Tank T-32	100	1,000,000
		Storage Tank T-33	80	800,000
		Storage Tank T-34	80	800,000

**Figure 3: Loss Estimate Calculator**